

Reduction of Irradiation-Induced Quality Changes by Rosemary Extract in Ready-to-Eat Turkey Meat Product

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Abstract

Ionizing radiation can effectively inactivate food borne pathogens in meat and meat products. However, at high doses, it may induce an undesirable color change and an off-odor which is partially due to production of volatile sulfur compounds. This study was conducted to investigate the effects of rosemary extract applied either in formulation or as a post manufacture dip on irradiation-induced volatile sulfur compounds as well as changes in color and lipid oxidation in turkey bologna. Turkey bologna was prepared from ground turkey emulsions with or without rosemary extraction at a final concentration of 0.075%. After cooking, bologna was sliced, sealed in gas impermeable bags, exposed to 0, 1.5 and 3.0 kGy gamma rays, and then stored at 5°C for up to 8 weeks. In the second experiment, slices of turkey bologna were dipped in water or 0.75% of rosemary extract for 2 min followed by irradiation at 3.0 kGy. Results showed that rosemary extract applied in formulation inhibited lipid oxidation in both irradiated and non-irradiated samples. Irradiation increased redness and lightness while reduced yellowness of samples. Rosemary extract was able to inhibit the irradiation-induced color changes. Irradiation induced production of volatile sulfur compounds, such as methanethiol and dimethyl disulfide. Rosemary extract applied either in formulation or as a dip, however, did not significantly reduce the formation of the volatile sulfur compounds.

INTRODUCTION

Ionizing radiation is a non-thermal processing technology used for retarding fruit ripening, disinfecting fruits and vegetables, and inactivating food borne pathogens and spoilage microorganisms in many foods. Irradiation can kill, injure, and inactivate foodborne pathogens and therefore enhance the microbial safety on meat and meat products. However, commercial use of this technology is limited partially due to concerns on adverse effects of irradiation on product quality, such as changes in color and the development of an off-odor. When foods are irradiated, particularly at high doses, an off-flavor can develop. The off-flavor/off-odor induced by irradiation has been called "irradiation odor" and described as 'metallic', 'sulfide', 'wet dog', 'wet grain' and 'barbecue corn like' (Ahn and Lee, 2004). Evidence indicates that volatile sulfur compounds may contribute mostly to the off-odor caused by irradiation (Ahn and Lee, 2004; Fan, 2005). These compounds may include H₂S, methanethiol, carbon disulfide, methyl sulfide, dimethyl disulfide, and dimethyl trisulfide. Other possible non-sulfur volatile compounds that contribute to the irradiation odor include aldehydes, alcohols, and ketones.

It is believed that these compounds are generated from radiolysis of lipids and protein/amino acids. Meats and meat precuts are rich in protein and fat, which make them more susceptible to the development of irradiation-induced off-odor. Off-odor may become more a problem for ready-to-eat meat (RTE) products than for raw meat because RTE products are often consumed without further cooking. The off-odor in raw meat can be mostly eliminated during cooking. Therefore, techniques are needed to minimize or

reduce off-odor development and color changes in RTE meat products.

Rosemary and its extract contain high levels of phenolic compounds with very potent antioxidant activity. Many of these compounds have been identified. Among them, carnosol and rosmarinic acid are the most active components in rosemary (Inatani et al., 1983; Wu et al., 1982). Rosemary extract and its antioxidant components are as powerful and effective as some of the synthetic antioxidants such as BHA, BHT, and propyl gallate (Beltran et al., 2004; Sebranek et al., 2005). It has been used by the meat industry to preserve color and flavor, and reduce production of cooking induced off-flavor such as warmed-over flavor (Güntensperger, 1998; Nissen et al., 2004; Yu et al., 2002). The objective of this study was to investigate the effect of rosemary extract on irradiation-induced color, lipid oxidation, and off-odor compounds of RTE turkey bologna.

MATERIALS AND METHODS

Effect of Rosemary Extract in Formulation in RTE Turkey Bologna

Ground turkey breast purchased from a local butcher was emulsified with the following ingredients (w/w per kg meat): 1% sodium chloride, 0.5 % sodium tripolyphosphate, 1% dextrose, 20% deionized water, and either 0.04% vegetable oil (control), or 0.075% rosemary extract in vegetable oil. Emulsion was then stuffed into 2.5" fibrous casings and cooked in a smokehouse to an internal product temperature of 65.5°C. The bologna were sliced to a thickness of 4 mm, placed into gas impermeable foil bags, vacuum-packaged to 4 mm Hg, and stored overnight at 5°C before irradiation at 1.5 and 3 kGy. Irradiation was conducted using a self-contained gamma radiation source. The source strength at the time of this study was ca. 98,600 Ci with a dose rate of 0.095 kGy·min⁻¹. After irradiation, samples were stored at 5°C for up to 8 weeks. At 2 week intervals, sulfur volatile compounds, lipid oxidation, and color were measured. Volatile sulfur compounds were extracted using a solid phase microextraction (SPME) method, and analyzed using a GC equipped with a pulse flame photometric detector (PFPD). Lipid oxidation was measured using the thiobarbituric acid (TBA) assay. Color analysis was performed using a Hunter Miniscan XE meter (Hunter Laboratory, Inc., Reston, VA). Analysis of volatile sulfur compounds, color, and lipid oxidation have been described earlier (Fan et al., 2002; Fan et al., 2004).

Application of Rosemary Extract as a Post-Manufacture Dip

Sliced turkey bologna was purchased from a local supermarket. Each slice was dipped into 100 ml water or 0.75% of rosemary extract solution for 2 min at 23°C. During the dipping, the solutions were stirred using stir plates to ensure uniformity of treatments. The samples were then chopped into small piece (3 x 3 mm), and placed (10 gram) into 40-ml vials. The vials were sealed with screw caps and septa and stored at 5°C for 4 hours before irradiated to 3 kGy at 4°C. Volatile sulfur compounds were then measured using SPME-GC-PFPD as described before.

RESULTS AND DISCUSSION

Effect of Rosemary Extract on Formulation in RTE Turkey Bologna

1. Lipid Oxidation. TBA reactive substance (TABRS) values have been used as an indicator for lipid oxidation. TBARS values of control (no rosemary extract) samples were not significantly influenced by irradiation at either 1.5 or 3.0 kGy (Fig. 1). Adding rosemary extract in formulation reduced TBARS values by more than threefold. Irradiation did not induce lipid oxidation in samples that contained rosemary extract.

2. Color. Irradiation reduced the yellowness (b* values) of the control (no rosemary extract) bologna (Fig. 2). The b* values decreased with increasing radiation dose. Use of rosemary extract was able to lessen, but not completely eliminate, irradiation-induced changes in b* values. Irradiation increased the "a values", i.e., the redness of the control bologna. Use of rosemary extract completely reduced the increase in "a values" due to

irradiation (data not shown). Irradiation increased L* values of control samples (Fig. 3), indicating that irradiated samples were lighter than the non-irradiated samples. In samples containing rosemary extract, no significant lightness of samples was observed.

3. Volatile Sulfur Compounds. The amount of total volatile sulfur compounds increased with increasing radiation dose (Fig. 4). The amount of total volatile sulfur compounds was more than doubled in samples treated with 3 kGy compared with the non-irradiated samples. Rosemary extract had no effect on the irradiation induced production of volatile sulfur compounds.

Comparing retention time and spectra of sample peaks with those of authentic compounds identified volatile sulfur compounds. These compounds included H₂S, methanethiol, CS₂, dimethyl sulfide, dimethyl disulfide, and dimethyl trisulfide. Among the compounds, H₂S, methanethiol, and dimethyl disulfide were promoted by irradiation, dimethyl sulfide was only slightly induced by irradiation while CS₂ and dimethyl trisulfide were not significantly affected by irradiation (Fan et al., 2004). Rosemary extract promoted irradiation-induced H₂S levels. Overall, rosemary was unable to reduce any of the volatile sulfur compounds.

During storage, the levels of H₂S and methanethiol decreased rapidly in both irradiated and non-irradiated turkey bologna, probably due to their volatility. After 8 weeks of storage, H₂S levels became undetectable for control bologna. Other volatile compounds either had no consistent changes or even slightly increased during storage.

Application of Rosemary Extract as a Dip

Irradiation of commercial turkey bologna at 3 kGy induced formation of methanethiol, but reduced production of dimethyl sulfide and CS₂ (Table 1) while no significant effect was found on H₂S. More than a tenfold increase was observed for dimethyl disulfide in the irradiated samples compared to the non-irradiated ones. Results showed that dipping samples in rosemary extract prior to irradiation had no significant effect on production of any volatile sulfur compound.

Our results suggest that rosemary extract was effective in reducing lipid oxidation and color changes. To reduce the negative effect of irradiation on quality, several other natural antioxidants have been studied. Most of the antioxidants demonstrated an inhibitive effect on lipid oxidation, and some could prevent color change due to irradiation. Lacroix et al. (1997) studied the effect of rosemary and thyme powder on lipid oxidation of fatty acids induced by irradiation. They found that both spices significantly reduced the production of hydrocarbons and protected fatty acids from radiolysis. Similarly, marinating chicken legs with a mixture containing ground rosemary and thyme reduced oxidation of unsaturated fatty acid in the meat (Mahrouf et al., 2003). Chen et al. (1999) found that sesamol, quercetin and BHT were effective in reduction of lipid oxidation in both raw and cooked pork patties under irradiation. Rosemary oleoresin and rutin were effective in the reduction of lipid oxidation only in irradiated raw pork patties. The effect of antioxidants on color changes of raw pork patties were minor and inconsistent (Chen et al., 1999). Du and Ahn (2002) added several antioxidants in turkey sausage formulations, and found sesamol had the higher antioxidant effect in terms of TBARS reduction; Rosemary extract had the weakest antioxidant effect. The red color induced by irradiation was reduced by gallic acid, rosemary extract and sesamol. The amount of total volatiles was decreased significantly by the antioxidants, but the antioxidant had minimal effects on off-flavor induced by irradiation. Formanek et al. (2003) studied rosemary extracts in irradiated ground beef and found that both lipid oxidation and color change were inhibited by the addition of rosemary extract. Lee et al. (2003) found rosemary oleoresin and rice hull extract significantly reduced the amount of sulfur volatiles and lipid oxidation in irradiated raw turkey meat. Our results, however, showed a very limited effect of rosemary extract in the reduction of volatile sulfur compounds.

The results reported here suggested that rosemary extract was very effective in inhibiting changes in color and lipid oxidation due to irradiation. However, the production

of off-odor volatile sulfur compounds due to irradiation was not consistently reduced. Other antioxidants such as sesamol, vitamin E, and ascorbic acid also had a very limited effect on the production of volatile sulfur compounds (Fan et al., 2004; Fan, 2005). It is possible that the mechanisms that are involved in production of volatile sulfur compounds differ from those for color changes and lipid oxidation. Means to control the irradiation-induced off-odor compounds need to be developed.

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Tables

Table 1. Effect of rosemary extract dipping on irradiation-induced volatile sulfur compound production in turkey bologna. Extracted from Fan, 2005.

Dose (kGy)	Antioxidant	H ₂ S	CS ₂	MT	DMS	DMDS	DMTS
0	None	483a ^z	4973a	247a	505a	318a	107a
0	Rosemary	370a	4172a	232a	522a	174a	85a
3	None	522a	3524b	2126b	266b	4522b	418b
3	Rosemary	407a	3202b	2103b	277b	4763b	495b

^z Means with the same letters are not significantly different (LSD, P>0.05).

MT: methanethiol; DMS: dimethyl sulfide; DMDS: dimethyl disulfide; DMTS: diethyltrisulfide.

Figures

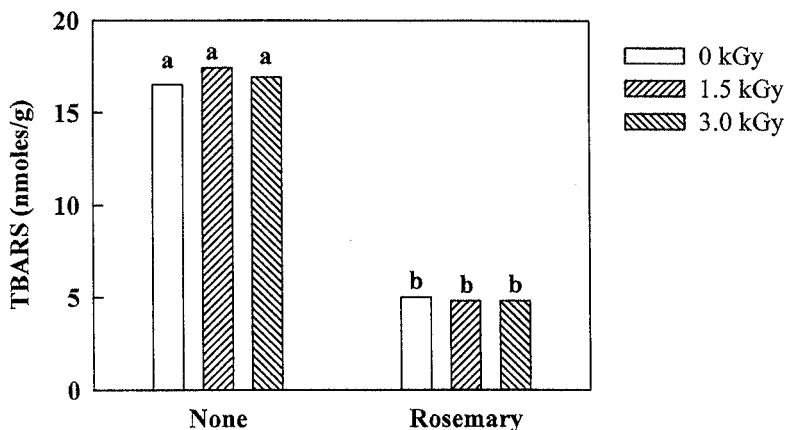


Fig. 1. Effect of rosemary extract applied in formulation on irradiation-induced lipid oxidation of turkey bologna. Bars with the same letters are not significantly different (LSD, P>0.05). Extracted from Fan et al., 2004.

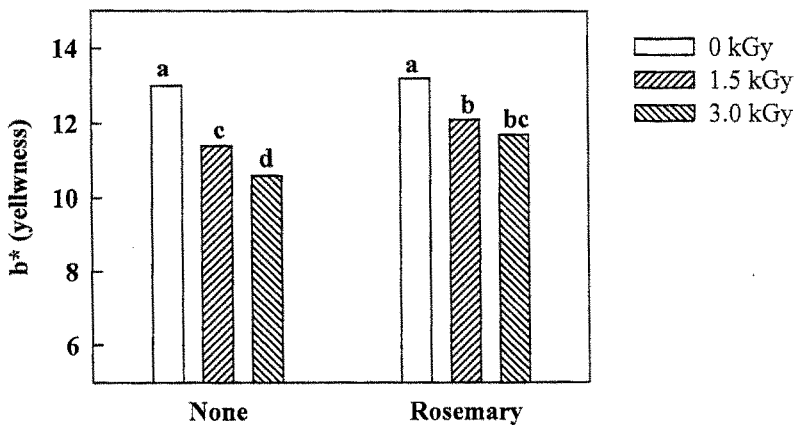


Fig. 2. Effect of rosemary extract applied in formulation on irradiation-induced color change (b^* values) of turkey bologna. Bars with the same letters are not significantly different (LSD, $P>0.05$).

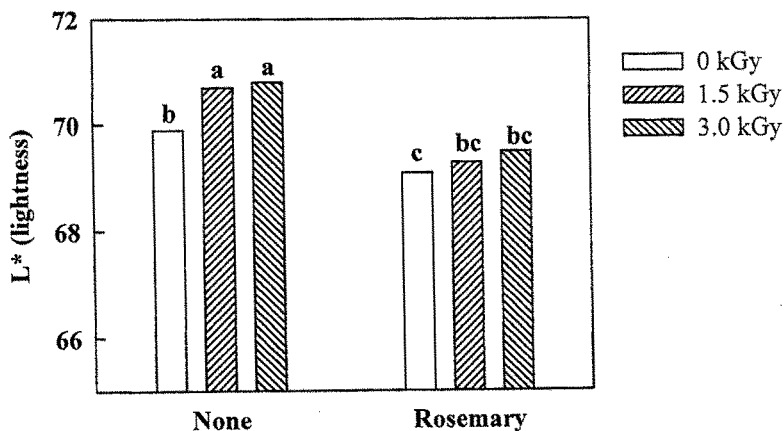


Fig. 3. Effect of rosemary extract applied in formulation on irradiation-induced color change (L^* values) of turkey bologna. Bars with the same letters are not significantly different (LSD, $P>0.05$).

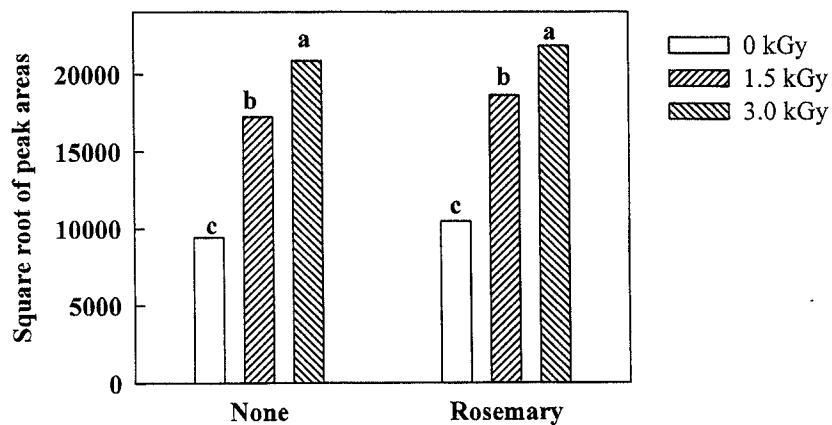


Fig. 4. Effect of rosemary extract applied in formulation on irradiation-induced production of total volatile sulfur compounds of turkey bologna. Bars with the same letters are not significantly different (LSD, $P>0.05$).

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